ABMS of the interaction between bees, flowers and insecticides using stochastic differential equations. ODD Protocol

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I. Overview

I-A. Purpose

The aim is to model the behavior dynamics of bees, flowers and pesticides, particularly the neonicotinoids, in order to analyze the impact that this pesticide has on the life of bees and how this is harmful to the development of the ecosystem as the pollination process of the flowers. The main characteristic of the model is the implementation of systems of stochastic differential equations for the modeling of the movement of the agents, which according to [1] results are more consistent with reality.

I-B. Entities, state variables, and scales

The entities that make up the simulation model from the point of view of agents are: bees, flowers and pesticides. For this case, particular characteristics are not considered for the global environment or environment. The state variables that agents have are: bees have an energy level attribute, flowers have an energy level and food level attribute, and finally, pesticides do not have state variables. With respect to the scale parameters of the simulation, a time step is considered.

I-C. Process Overview and Scheduling

Next, the order of the processes executed by the agents of the model and their respective order is described.
Bees:

1. Decrease your energy level.
2. Feed on the flower.
3. Interact with the pesticide.
4. Reproduction.
5. Pollination.
6. Death

Flowers:

1. Decrease your energy level.
2. Change the color according to health.
3. Recover food level.
4. Death

I-D. Design Concepts

I-D1. Basic principles: The relationship that exists between bees and flowers is considered from the ecological point of view as a mutualistic relationship in which individuals of different species benefit from the biological aptitudes of other species, particularly the role of bees in contributing to the process. of pollination of flowers and flowers in the feeding of bees. However, the presence of pesticides harms this interaction causing the bees to die and the ecosystem to become unbalanced.
The main characteristic of the model is the dynamics of the movement of bees through systems of stochastic differential equations. According to [1] its movement can be analyzed as a derivation of a stochastic process, which provides a more realistic analysis of the phenomenon according to studies of that movement. According to the needs of our problem, we have used a system of equations that has the quality of being attracted to a particular point, which in this case is allusive to flowers. The hypotheses that govern the dynamics of the model with respect to the agents are the following: the bees are attracted to the nearest flower, the food capacity of the flowers decreases as the bees make use of it, there is no delay in the pollination of the flowers by the bees and the birth of the flower, each flower has the same life time and the flowers are not affected by the pesticide. The previous hypotheses have been considered from the empirical point of view and through documentaries about how bees have been dying and their impact on the ecosystem.

I-D2. Emergence: The outputs of the model are the number of bees and flowers at the end of the simulation time and how they are altered according to the presence of pesticides. The sensitivity of these variables is analyzed in the same way according to the main parameters that describe the model.

I-D3. Adaptation: The adaptive behavior of the agents can be seen in the bees in relation to the flowers with which they are attracted and this depends on the distance that the bees are from. This behavior is due to the characteristic of reversion to the mean of the system of stochastic differential equations.

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I-D4. Objectives: The goal of the bees is to survive by means of the flowers and that the latter benefit from this interaction and contribute to the pollination of the same.

I-D5. Learning: The model does not consider some type of learning.

I-D6. Prediction: The model is not considered as a forecasting tool

I-D7. Sensing: Bees feel the effects of pesticides around their location and how they affect their energy level and then move away from their position. In the same way, the flowers feel how their level of available food decreases given the interaction with the bees.

I-D8. Interaction: There is no interaction with agents of the same type, that is, bees with bees, flowers with flowers or pesticides with pesticides. The interaction that occurs in the model is on the part of the bees with the flowers and the bees with the pesticides. The interactions mentioned above are those that govern the dynamics of the ecosystem and mutualistic relationships between different species.

I-D9. Stochasticity: The initial position of bees, flowers and pesticides distributes evenly in the plane. The equations that describe the movement are the mean reversion stochastic differential equations with additive noise.

I-D10. Collectives: No groups are presented in the present model.

I-D11. Observation: It is necessary to analyze the behavior of the attributes that make up bees and flowers over time, therefore it is necessary to implement the main descriptive statistics and the use of graphs that describe the dynamics of the system.

I-E. Initialization

The following describes the initial values of the model:
Number of bees:
Number of flowers:
Number of pesticides:

I-F. Input Data

In our case, input variables are not considered.

I-G. Submodels

The processes that make up the model are described.

- Decrease your energy level: In each period of time the energy level of the bees is reduced by one unit due to the movement, natural process of the agent.
- Feeding the flower: The moment a bee reaches a certain flower, it recharges its energies and acquires the possibility of pollinating the flower.
- Interact with the pesticide: as the bees approach the pesticides they will suffer a significant decrease in their energy level.
- Reproduction: according to the energy levels of the bees, the reproduction of the species is carried out, allowing new agents to enter the simulation.
- Death of bees or flowers: according to the level of energy and interactions with other agents, if the energy level becomes less than or equal to zero the agent dies and leaves the simulation.
- Change the color according to health: Depending on the level of energy possessed by a flower, it will have a certain color.
- Recover food level: as time passes, the flowers will recover the ability to feed more bees and be attractive to them.

II. Descripción del sistema

Referencias

[1] F. Lenz, A. V. Chechkin, and R. Klages, "Constructing a stochastic model of bumblebee flights from experimental data," *PLOS ONE*, vol. 8, no. 3, pp. 1–7, 03 2013. [Online]. Available: https://doi.org/10.1371/journal.pone.0059036